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## Source-Material on New Technology for Engineering Education

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## SOURCE-MATERIAL ON NEW TECHNOLOGY FOR ENGINEERING EDUCATION

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### Summary

Monographs are being prepared from research reports for use as supplementary source material in engineering classrooms. Each Monograph contains and develops one central idea and is planned for use in one to three class periods of a course. The three prominent engineering science subject areas of thermodynamics, heat transfer, and control systems were selected in which to establish a pilot program for creation and testing of these documents. The main objective is to speed the results of new technology resulting from research into the classroom. This NASA Pilot Program is an experiment of the College of Engineering at Oklahoma State University supported by a contract with NASA Office of Technology Utilization.

The results of 18 months in the pilot program to create, disseminate, and evaluate the effectiveness of the Monographs as source material in engineering education are very encouraging. Several different modes for generating the Monographs by senior professors, junior professors, and graduate assistants have been found that are satisfactory and some that are not very effective. Sufficient experience has been obtained to provide confidence in extrapolating the program to a broader system of production for the Monographs. A sufficient number of evaluations have been obtained from classroom use by professors to assure that the product is a useful one. An initial investigation into industrial interest in these same Monographs has produced a very positive response as well.

There are still some unanswered questions to the problems to be encountered in placing the Monographs into commercial publication. The program is felt to be of sufficient interest and potential value to warrant the preparation of proposals to expand the pilot program into a broader program involving qualified authors and writers in various universities around the country.

### Introduction

On March 16, 1966, the College of Engineering at Oklahoma State University submitted an unsolicited proposal entitled "A Pilot Program for Selecting, Editing, and Disseminating Engineering and Scientific Educational Subject Matter from NASA Technical Reports" to the Office of Technology Utilization of the National Aeronautics and Space Administration. The objective was to systematically review NASA Technical Reports for information that would be of significant benefit to the engineering and physical sciences educational programs. The resulting information would be formulated as Monographs suitable for

supplementary text materials in advanced undergraduate and graduate classes as well as in technical short courses and seminars. A contract with NASA was initiated effective June 1, 1966, which has resulted in the work described here.

A program objective was to provide up-to-date instructional material derived from current research as rapidly and as efficiently as possible to faculty members engaged in teaching. Information about new technology usually is published first as a research report and then tends to migrate through other forms of published material until it makes its way in textbooks. The time necessary for new technology to be included in the textbook typically can be five years. The textbook contains the majority of material possible for a professor to use in his course, and this busy person seldom has time to augment his material with many recent research results. In the meantime, new technology is being created at a faster and faster rate further aggravating the situation of using outdated material in university classrooms. The preparation of a Monograph directly from the first research report would attempt to shortcut this time by perhaps several years. This preparation would conserve the time of many faculty members by having the search and writing done by a few with the resulting Monographs being made available to all.

A program that systematically searches for new technology and prepares it for educational use also may make available many new developments that otherwise might contribute only to the solution of a single problem. The inevitable result otherwise would be the reinvention or rediscovery of technology that would not otherwise have been necessary.

### Subject Areas

The subject areas of Heat Transfer, Thermodynamics, and Control Systems were selected in which to create Monographs during the pilot program. Even though there would be no attempt to write Monographs to cover the complete range of these areas, the broad subject areas appeared desirable. In Heat Transfer both radiation and convection heat transfer are treated. The Thermodynamics area is rather specialized in the Monographs prepared. In the Control System area a wide range of subjects are covered.

The NASA research program generates certain specialized areas which are unique to NASA, but, in addition, nearly every standard technology is

represented by use to a greater or lesser degree. Many subject areas could be developed into a Monograph program from NASA work as well as from other major research programs.

### Procedures for Producing Monographs

#### Modes of Operation

The mode of operation used to produce Monographs must be attractive to the senior author to gain his participation. He is the key person in the production of Monographs and is expected to have the following qualifications: an author of a recent textbook or a recognized authority in his field, an experienced and mature engineer in his field, and an experienced and knowledgeable teacher in engineering. In the process of producing Monographs he must be able to recognize new and significant material in his field; he must be able to develop a complete and accurate presentation of the new contribution to technology; and he must be able to write or edit the Monograph in such a way as to make it valuable as supplementary teaching material in his field. An individual with these qualifications has many places where he can fruitfully apply his labors, so a satisfactory mode of operation of the Monograph program is important.

Two main modes of operation have been used for writing Monographs with a third mode being a slight modification of the second. In the first mode, the senior author does all of his own development of material and writing with only minor assistance from a graduate associate where desired. This mode uses a considerable amount of the senior author's time. In the second mode, an experienced engineering professor in the field takes the material selected by the senior author and prepares it as supplementary textbook material under the guidance of the senior author. In these two modes, both the senior author and the supporting experienced engineering professor have been regular participants in the program. The third mode modifies this procedure slightly by hiring the experienced engineering professor as a consultant at an appropriate hourly stipend to prepare the Monograph from the material selected by the senior author. The senior author then edits and prepares the material for final typing. The experience in this mode of operation was obtained under the guidance of Dr. John A. Wiebelt as senior author with Dr. Paul A. Miller of Kansas State University, who was a former student of Dr. Wiebelt's, doing the writing. This procedure is closely related to the writing arrangement textbook authors have with professional book publishers.

#### Selection of Material

The first task in preparing a Monograph is to obtain new material appropriate for use in the classroom. A graduate associate was used in the initial search under the guidance of the senior author. The senior author orientated the Graduate Associate in the subject area in which he was to work, giving him key ideas of what to expect. The most productive place for research reports from NASA Laboratories or NASA Contracts was the STAR abstracts, A Selected Listing of

NASA Scientific and Technical Reports for 19-- , and the AIAA, American Institute of Aerospace Abstracts, publications. The abstracts obtained in this manner were reviewed with the senior author who selected those for which the complete report should be obtained. Sufficient material was obtained in all three subject areas for the pilot program by this technique.

Two other techniques used to discover appropriate material for Monographs were computer oriented information retrieval programs and personal contacts and visits with known centers in the senior author's area. Initial use of the information retrieval through the Technology Utilization Division produced some peripheral reports of interest but otherwise rather useless material for this purpose. No further refinement of indexing was attempted at this time since sufficient material was being discovered through the abstract searches. Computer oriented information retrieval systems should be of great value in any expansion of the pilot program into a broader program.

Since the senior author is acquainted with those contributing in his field, he is in a position to learn of material directly from centers doing this research. Several of the senior authors did visit some of the NASA research centers to develop such contacts with good results. One item discovered was the availability of internal reports which do not reach the open literature. Some of these external reports, particularly in design, appear to make significant contributions to new technology.

#### Writing the Monographs

Varying degrees of effort are required to turn the information in a report or reports into a form appropriate as a Monograph. Much of the effort in the initial searches involved obtaining research reports which could be readily transformed from their present form to that of a Monograph. There have been some significant exceptions which indicate the variation in effort required. When more than one report serves as a basis for the Monograph, significantly greater effort is required to produce a single Monograph. Even greater effort is required if the material in a report is new technology but is too limited or incomplete to serve as satisfactory educational material.

General guidance for the senior authors is provided for both the philosophy behind the Monograph concept and for the specific Monograph format expected, yet he is left with a great deal of flexibility in the actual writing of the Monograph. This guidance information is included in Appendix I. Following the writing of the Monograph, the graduate associate is again used to help design and work out a solution to a problem using the new technology discussed. Following editing of the Monograph, the home problem, and the home problem solution, final typing and drafting are accomplished and the Monograph is readied for multiple copy reproduction.

Prior to final reproduction, several copies of the Monograph are made which are sent to the authors of the original reports from which the

Monograph was written. The objective is to get a critique of the technical content of the Monograph from one who is intimately acquainted with the work. This review is quite useful when it can be obtained. When this is not possible, the senior author usually will have a colleague who is also competent in the field to review the Monograph for technical content. The format and the presentation of the Monograph as educational material, of course, is the responsibility of the senior author as an experienced, competent engineering teacher in his field.

#### Reproduction

Following the technical review and any alterations found appropriate, the Monographs are typed onto multilith mats for reproduction which results in printed material similar to that of this report. There are two formats produced of each Monograph, an Instructor's Monograph and a Student's Monograph. They differ only in that the student's copy does not have front and back covers, the Instructor's Guide for use of the Monograph, and the solution to any home problems in the Monograph. The usefulness to the student of a copy is similar to the usefulness of his textbook in providing him with basic technology.

#### Procedures Used for Trial Dissemination

An objective of the program was to determine the effectiveness of the Monographs by dissemination into classrooms, seminars, and research programs in universities throughout the United States. The schedule of writing and reproducing Monographs was sufficiently tight to require personal contacts with prospective evaluators if a test were to be obtained during the second semester of the 1966-67 academic year. These contacts were made by the senior authors with known co-workers in his field at other universities and resulted in reasonably good response. Due to the longer time necessary to prepare a Monograph than that originally thought and due to the delays in production of the Monographs, only a few items were actually sent to professors for use during the second semester of 1966-67.

At the time an individual professor expressed any interest in participating in evaluating Monographs he was sent a letter explaining the program and a set of abstracts of all Monographs. Then, when the professor made specific requests for those materials appropriate for his use, the materials were sent together with evaluation sheets and with an indication of how important his evaluations would be to the success of the program. Materials were supplied to the professor free of charge in exchange for his evaluation of the effectiveness of their use as educational material.

#### Results from Program Implementation

Up to the present time 17 Monographs have been written. The titles of the Monographs are given by subject areas in Appendix II. The procedures discussed in the previous sections were those used to accomplish these results. The rest of this section will be used to summarize the accomplishments when these procedures were implemented.

#### Selection of Material for Monographs

Some statistics on the effectiveness of the use of reviewing abstracts in the Control Systems area will give an indication of results of this method of seeking material. From the survey of the STAR abstracts over several recent years 146 reports were considered. Of these 146, 36 were reviewed extensively, some by two or more members of the group for a total of 64 reviews. Of those reviewed 9 reports were chosen from which the 6 Monographs in the Control Systems area were written. Of the 27 reports remaining of those extensively reviewed, 15 additional reports were felt to have classroom applications. Of these, 5 seem best suited for Monograph preparation.

There is a source of what appears to be useful material for Monographs which are not published in the open literature. They are referred to as "internal" reports. These are normally generated to provide for satisfactory operation of work being conducted at a particular research center, but, for some reason have not been published where they would be abstracted by STAR or AIAA.

#### Writing the Monographs

Once appropriate material has been selected by the senior authors a wide range of effort is still required to complete the writing of a Monograph. Some reports are in a format near enough to one useful in the educational process that a relatively few hours are required to finish the preparation. Monographs HT-7 and HT-8 are examples where approximately 40 and 24 hours, respectively, of actual writing time were required to make the conversion. Additional man-hours of time are required to prepare the Monographs for reproduction estimated here to be: approximately 10 hours to design and work a home problem; 5 hours of editing by senior author; and 25 hours for the rough draft and the final draft typing together with preparation of illustrations. For HT-7 this would total 45 man-hours of professional time and 35 man-hours of skilled time. Undoubtedly, this is the lower limit of the time necessary to prepare a Monograph following delineation of material.

The variables that have been found to increase the time necessary to complete a Monograph are numerous. If two or more reports are used, the preparation is more time consuming. When the subject area is covered inadequately, the professor may find it necessary to prepare additional information to make a complete topic. The computer has become a valued tool in many analytical techniques not previously solvable. Usually these computer programs are quite elaborate and need simplification for the learning process required in the classroom. Lastly, (as was found in CS-2) some improper assumptions on the part of the original author may lead to errors that the author must reconcile through further development and discussions with the original author. As an estimate, the professional man-hours could easily increase by a factor of four over the 45 man-hours established in the previous paragraph.

During this program, the majority of the writing effort of a professor was provided as a continuous 1/4 time. With the other 3/4 time assigned to other duties and with the many interruptions during



the day, this mode of operation did not provide an efficient use of the professor's efforts. Writing technical material just cannot be done efficiently or effectively in two hour sections. During writing periods, at least 1/2 of the professor's time should be allotted. The minimum time established for the two Monographs HT-7 and HT-8, was accomplished with full time assigned during the actual writing of the Monograph by the consultant.

#### Dissemination of Monographs

The timing of the production of Monographs was supposed to be so that evaluations could be obtained from uses in the classroom during the second semester of the academic year starting the last of January, 1967. The timing could not be met, primarily because of the longer time necessary to write a Monograph over that originally expected. All but 1 of the original 15 Monographs, plus 2 additional Monographs in the Heat Transfer area were completed by January, 1968.

Despite the lateness of availability, sufficient numbers of requests for the materials were received to conclude that there was both an interest in the material and that the methods of publicizing their existence were effective. The statistics on dissemination of Monographs shows the total number of Instructor's copies, indicating individual professors making requests, ranged from 12 to 28 depending on the Monograph. The total requests for the initial 15 Monographs were 357 Instructor's copies and 1,943 student's copies. These requests came through contacts made by the personal calls of the senior authors, through displays and papers at meetings, and through word of mouth. The effectiveness of dissemination appears to be reasonably good for the Monographs. All of the Monographs have 12 or more professors involved.

#### Monograph Evaluations from Professors

Monographs were not available in time for any significant use in spring classes and there were not many classes conducted during the summer in most universities. Only 5 of the 15 Monographs have been used by professors and corresponding evaluation sheets returned. They are HT-1, HT-3, HT-4, TD-3, and CS-5. From these evaluations some general conclusions can be made. The Monographs were mostly used in the classroom rather than in other applications, and none were used in research as such. Although the general material was familiar to some of the instructors, the formulation of the material in this form was found suitable for use. Perhaps a disappointing thing in the early returns was the number of times the instructor did not require the student to work the home problems. The format and the amount of material seemed appropriate for the professors involved, and references were used in most cases. The general observation of the professors submitting the evaluations is that all thought they were of some use and half of them felt that Monographs would be of great assistance in the classroom use. The Monographs were used almost entirely in context with closely related material in course presentation. From the written comments the feelings appear to be that the Monograph concept is interesting and

useful. Other comments include some specific suggestions on Monograph format and the level in the technical content for which the particular Monographs might be used.

The number of completed evaluations is small, but there appears to be every reason why the Monograph would be a desirable supplementary aid in the classroom. Additional evaluations in classrooms by professors will certainly contribute to refinements that will make the Monographs even more effective in their uses. These are anticipated from uses in the Spring term of 1968.

#### "Education Briefs" to Industry

The NASA Technology Utilization Division has in operation a method of sending one page "Tech Briefs" to industry on subjects generated in NASA research that might be applicable there. As a corollary to this program, Mr. Kenneth T. Jacobs of the Technology Utilization Office of the Goddard Space Flight Center produced one page "Education Briefs" from the abstracts of four of the Monographs, three in Heat Transfer and one in Thermodynamics. Mr. Jacobs routed these to the industrial companies normally receiving the "Tech Briefs" and obtained a very favorable response compared to the ratings normally obtained for such exposures. There were 243 approaches of which 36 per cent responded. Of those responding 70 per cent were positive, 14 per cent were negative and 14 per cent were other responses. This response by industry to the Monographs gives a significant support to the requirement of getting new technology as rapidly as possible into use through special preparation of educational materials. This response was very much more positive than the average "Tech Brief" response expected on similar exposure to this sample of industry.

#### Some Cost Figures from Program Implementation

This program in producing and testing written materials as supplementary aids in engineering education has been a research program in that the techniques and formats were developed as well as actual products produced. In analyzing the cost figures necessary to be able to provide a probable unit cost in a continuing program of this type, it is difficult to separate the development costs from the production costs in the original program. Nevertheless, estimates of the cost allotment from the original program are helpful in making some initial estimates of future cost of production.

#### Preparation of Monographs

The costs listed below by Monograph numbers are divided by senior author. The costs included were the author's, the graduate associate's, the secretary's, and the special service's time necessary to search for materials, establish procedures, write the Monographs, obtain technical approvals from original authors, and make corrections required for the Monographs listed.

Heat Transfer (Radiation)	
HT-1, HT-3, HT-4	\$12,000
HT-7, HT-8	1,700

Heat Transfer (Conduction)	
HT-2, HT-5, HT-6	\$11,400
Thermodynamics	
TD-3, TD-4	10,500
Thermodynamics	
TD-1, TD-2 (not completed)	6,800
Control Systems	
CS-1, CS-2, CS-3	
CS-4, CS-5, CS-6	19,800

These figures include the standard overhead, vacation, personnel benefits, etc., normally required for these persons but does not include the costs of the Program Administrator's office. The average cost then turns out to be about \$3,700 per Monograph with a low of \$850 per Monograph and a high of about \$5,000 per Monograph.

#### Reproduction of Monographs

Following the typing of the final Monograph on multilith mats the reproduction costs per Monograph can be determined quite accurately. The total cost of drafting services, art services, and production of the front and back covers for the first 15 Monographs came to \$1,094. The cost of running the reproduction process, assembling, and binding came to \$1,177 for the first 9 Monographs. These figures result in averages of \$73 and \$130 per Monograph, respectively or a total of \$203 per Monograph for the average. This resulted in 100 Instructor's copies and 400 Student's copies of each Monograph.

#### Conclusions and Recommendations

The initial objective of the NASA Pilot Program at Oklahoma State University was to reduce the time between discovery of specific scientific and engineering information and its use in technological development. Our initial experience in producing and using Monographs created for supplementary use in the classroom leads us to believe that we have produced a mechanism for reaching this objective. The Monographs are useful as supplementary educational material and have reduced the time between development of a technological achievement and its introduction to engineering students and practicing engineers. They provide an appropriate method to get information of this type to individuals in industry as was shown through the "Education Brief" experiment.

Perhaps more important, the same document used in the classroom provides the information with a multiplicative effect by exposure to students who soon are the practicing engineers in industry who will have the new technology with which to work.

The concepts developed in the NASA Pilot Program are obviously applicable to research and development documents reporting on the creation of new technology from any organization. There are special problems in seeking appropriate material and choosing subject areas, but a mode of operation developed for the NASA generated material could be placed into operation in the Atomic Energy Commission, the Department of Defense, or any industrial laboratory producing appropriate documents. A significant amount of progress has been made in determining an effective and efficient means of producing Monographs useful in the classroom during the contract. The most satisfactory technique is not unique, since it varies with senior authors and subject matter. The sources of information even from just the NASA organizations have not been investigated sufficiently to establish the needed confidence in the results from literature searches. Finally the Monographs need further use in the field with evaluations by the users as to their effectiveness to confirm the initial conclusions and allow refining of these supplementary educational aids resulting.

In addition to the refinement of the searching techniques and the modes of operation desirable in the NASA program, working in other areas of technology than those generated by NASA is of most importance. The NASA organization is ahead of other federally sponsored organizations in the use of technology "to insure that developments from NASA's scientific and technological programs be retrieved and made available to the maximum extent for the nation's industrial benefit in the shortest possible time . . .". (Quoting NASA Administrator James E. Webb in his definition of the Technology Utilization Program). To allow a large comprehensive recovery of much of the technology throughout federally sponsored programs, for instance, further experience is most desirable in creating Monographs from materials resulting from searches in each of the sponsoring organizations. We are convinced that the educational procedure investigated under the NASA Pilot Program has as good as, or a better opportunity of Insuring Administrator Webb's goal for the Technology Utilization Program as any technique yet devised.

## Appendix I

### Guidance to Author for Preparing Monographs

A. General Philosophy for the Preparation of Monographs. A Monograph is a technical paper primarily based on one or more NASA research reports and commonly supplemented by other material and is designed to supplement textbook and class note material in a course of instruction. The author of the Monograph must keep in mind the usefulness of the Monograph in a class. It is desirable to keep the amount of material to a minimum and yet the material should be sufficiently complete for the use of the teacher in the class without undue reference work on his part. Where possible, the Monograph should contain and develop only one central idea. It is important that the Monograph be written for the student at the proper level. Use of a Monograph should acquaint the student with the format and purpose of a technical paper as well as contribute some technical information to his course.

### B. Description of Monograph Content.

1. Abstract of the Monograph. The abstract should contain the kernel of what the Monograph is about and why it will be useful. The abstract should follow the usual procedure for abstracting a technical article.

2. Main Body of the Monograph. The main body of the Monographs should consist of material that can be used in a class with a minimum amount of extra preparation and explanation to the class. The material should be written on a level corresponding to the level of the student to which the Monograph is addressed. It would seem important that figures be prepared in such a way that transparencies or slides could be easily made and successfully projected in the classroom. In general the Monograph should be made to cover some integral number of class periods. In particular, it is expected that the Monograph will be used in units of single class period sessions. However, if material is such that its importance justifies more than one class period, then up to three class periods might be considered.

3. References. The references should be pertinent and should be chosen carefully to serve some well-defined purpose. Avoid long lists of bibliographical material unless such a list is needed for a specific purpose. The reference information should be given with some indication of what will be found in each individual reference. If only a single short item is to be included in this reference material, it should be placed in the Monograph instead of being referenced.

4. Supporting Material. Whenever possible the author should indicate in the Monograph an example of the use of the material in the report from which the Monograph has been taken. It would also be desirable for the author to prepare an example or home problem to be assigned by the instructor. These home problems should also be accompanied by solutions attached to the Instructor's Monographs.

5. Instructor's Guide for Monographs. A guide for the instructor for the use of the material in the Monograph should be included in each Monograph and where possible kept to a minimum of one page. The information to be presented in this guide is listed below:

- (a) Educational level of the Monograph
- (b) Prerequisite course material
- (c) Estimated number of lecture periods required
- (d) Technical significance of the Monograph
- (e) New concepts or unusual concepts illustrated
- (f) Suggestions on how the Monographs can best be used
- (g) Other literature, Briefs, or Monographs of interest to this subject
- (h) Other reports reviewed by the editor in preparing this Monograph
- (i) Who should be contacted for further investigation
- (j) General subject areas available in other Briefs or Monographs

6. Format of Monographs. There will be two different forms of Monograph prepared for each Monograph written. One will be for the use of the instructor and the other will be for the use of the student. The general content of the Monographs for the instructor is listed below in the order recommended for assembling the Monograph. In order to discriminate between the two, the student's Monograph and the Instructor's Monograph will have different colored covers or the Student's Monograph will be an unbound paper. The following order is suggested for the Monograph:

- \* Front
- \* Title Page
- \* Foreword on NASA Pilot Program
- \* Report or reports from which this Monograph was primarily taken
- \* Instructor's guide
- \* Abstract
- \* Main Body
- \* Summary
- \* References, Specific and General
- \* Illustrative problem
- \* Solution to illustrative problem
- \* Transparencies of figures

\* Contained in a student Monograph

Those pages in the instructor's Monograph not included in the student's Monograph will be printed on different colored paper than the common material. This will make the instructor immediately aware of the information available to the student.

## Appendix II

### Monograph Titles

#### Heat Transfer

- HT-1 Calculation of Radiant Heat Exchange by the Monte Carlo Method
- HT-2 A Generalized Correlation of Vaporization Times of Drops in Film Boiling on a Flat Plate
- HT-3 Method for Estimating Ratio of Absorptance to Emittance
- HT-4 Formulas for Radiant Heat Transfer Between Nongray Parallel Plates of Polished Refractory Metals
- HT-5 Pool Boiling Heat Transfer at Reduced Gravity
- HT-6 Condensation of Liquid Metals
- HT-7 The Method of Zones for the Calculation of Temperature Distribution
- HT-8 Heat Pipes and Vapor Chambers for Thermal Control of Spacecraft

#### Thermodynamics

- TD-1 Calculation of Complex Chemical Equilibria
- TD-3 Critical Flow of Real Gases Through Nozzles
- TD-4 Thermodynamic Consistency of Vapor-Liquid Solubility Data

#### Control Systems

- CS-1 An Example of Compensation Network Design
- CS-2 An Application of Root Locus Techniques to Lunar Vehicle Control
- CS-3 An Example of Nuclear Rocket Control Design
- CS-4 An Example of Bang-Bang Control System Design
- CS-5 Controller Design for Nonlinear and Time-Varying Plants
- CS-6 An Example of Optimal Control Design